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tion (for we have not yet found leisure to do justice to the work) shows that the text-revision is carefully made. The introduction of eighty-four pages gives to the reader all the necessary information of this most prominent church father. On account of the importance of the books of Origen, we hope to give a further analysis of Professor Koetschau's edition. P. C.

ZOROASTRIANISM IN THE LIGHT OF THEOSOPHY. Being a Collection of Selected Articles from the Theosophical Literature. Compiled by *Nasarvanji F. Bilimoria*. Pp., 362+xxiv. Bombay: "Blavatsky Lodge," Theosophical Society. Madras: Headquarters, Theosophical Society, Adyar. London Agents: The Theosophical Publishing Society, 26 Charing Cross, S. W.

The articles collected in this volume possess different values, and while they are full of vague ideas, as is usually the case with theosophical literature, they also contain suggestive thoughts, which will prove valuable hints to students of Zoroastrianism. The chief editor, Mr. Nasarvanji F. Bilimoria, is one of the most important contributors, and his articles touch upon the most important points, such as the "sacred haoma tree." Other writers represented are H. S. Olcott, Kharsedji N. Seervai, N. D. Khandalvala, B. E. Unwala, Walter R. Old, Baker Hudson, and Alexander Wilder. The articles are entitled: "The Spirit of the Zoroastrian Religion," "The Septenary Nature of Man," "The Sun as a Symbol of Ahura-Mazda," "Philosophy and Ethics of Zoroaster," "Sun-worship and Fire-worship," "Transmigration in the Avesta," "The Ceremonies," etc., etc. A great number of the contributors being Parsis, the book may fairly be considered a sign of the interest which they take in their venerable religion. The influence of Madame Blavatsky and Mrs. Besant upon the style of reasoning is apparent; but the general spirit of the book is praiseworthy, and we cannot do better than to repeat the following lines of Prof. W. M. Flinders Petrie, in a letter to the secretary of the Parsi Panchâyet, Bombay: "I need hardly say how gladly I should do anything I could to forward research in the Irânian regions; and what satisfaction it is to see the able descendants of so noble a race turning their attention to research in their history and origins." P. C.

VORLESUNGEN ÜBER DIE PRINCIPE DER MECHANIK. Von *Ludwig Boltzmann*. Erster Theil. Mit sechszehn Figuren. Leipsic: J. A. Barth. 1897. Pp., 241. Price, 6 M.

Professor Boltzmann, the versatile and indefatigable occupant of the chair of theoretical physics in the University of Vienna, has been hovering of late years with peculiar predilection over the problems that unite, or rather separate, physics from philosophy, and his views, both from their outspokenness and their intrinsic fitness, deserve consideration. Two scientific thinkers seem to have furnished the greater part of the stimulus to his reflexions—Hertz and Mach—and in express or tacit reference to these men he has developed his views.

Hertz in particular he treats with loving kindness. The expositions in the Introduction to the latter's *Mechanics* seem to have made a profound impression upon him ; their beautiful and clear-cut language, which reminds us of the lucid style of David Hume or of D'Alembert, and preserves all the traditions of the eighteenth century, have given to Hertz's ideas a precision and faultlessness of form which ensure their retention by all who have ever lent themselves to their influence. These ideas would undoubtedly be denominated "superficial" by the analytical psychologist, and by the ponderous ontological philosopher, who estimates the value of a system by its unintelligibility; and it must be admitted that they do smack of the art of the *littérateur*. But they are clear, and that is half their victory. It is therefore clearly intelligible that Professor Boltzmann's views should throughout be saturated with Hertz's phraseology. The influence of Mach has been more subtle, but the undercurrent is plainly perceptible. The notions of mental adaptation, of the rôle of comparison in science, etc., not to speak of technical contributions proper, play a considerable part in the development.

We are concerned, in this notice, with Professor Boltzmann's views of the theory of scientific explanation only and not with his system of mechanics ; he has developed these views partly in the introductory sections of the present work, and partly in his essay *On the Methods of Theoretical Physics* in Dyck's catalogue of the Nüremberg-Munich Exposition of Mathematical and Physical Models. We shall make use of both sources in our remarks.

The discussion largely centers about Kirchhoff's definition of mechanics, in which the term "description" figures; and, since the far-reaching implications of that term and of its correlative "comparison" are not generally and exactly understood, we shall first give a brief exposition of their meaning, making this exposition the burden of our remarks.

Bare description does not necessarily constitute the essence of science. When Kirchhoff said, to the horror of most contemporaneous physicists, that it was the object of mechanics to *describe* in the simplest and completest possible manner the motions occurring in nature, he demonstrably did not mean that the essence of mechanics was a statistical word-for-fact tabulation of the motions of the universe ; if he had, the *Mécanique Analytique* of Lagrange might have been written by a Patagonian savage. He merely aimed at a restoration of the Newtonian ideal of science, which had been intimated before him by D'Alembert, and had been stated contemporaneously with him by Mach. That ideal was, in stating the facts to state *only* the facts, or relations of facts, involved, and not to state purely superfluous matter and creations of the imagination, or even analogies, not involved. It was description of actualities as opposed to description of fictions. *Hypotheses non fingo*, said Newton ; "I make no hypotheses." I state only what is necessary and sufficient to *describe* what gravitation is, what moving force is ; I supply no supererogatory speculation as to what are their occult causes. The real aim of Newton and Kirchhoff, thus, was the ousting of metaphysics from science.

But there is another feature involved that is not usually considered. The law of the inverse squares, for example, *is* a description of the motions of the heavenly bodies, but it stands on an entirely different plane from the description of a topographical chart of the State of Illinois. The ultimate object in *building up* the science of mechanics is *to afford the means* for rapidly and completely describing the motions of nature; the formulæ of mechanics *potentially* involve the description, but in themselves they are more than the description. The elements of form economy, and necessity are very insufficiently emphasised here.

And now as to comparison. There is a deep significance in the remark which Agassiz is said to have made to the unsuccessful naturalists of America in his day: "You are too much *déscriptif*, too little *comparatif*." The element of comparison is at the basis of all scientific explanation; and scientific description, understood in its highest as well as in its lowest sense, always proceeds by comparison. When the savage saw a spirit in the magnet; when Newton likened the falling of the moon to the earth, to the phenomenon of the falling of a stone to the ground; when Pascal repeated with mercury in water the experiments which nature was daily making in the atmospheric ocean around him; when electrified bodies were conceived to be freighted with fluids which attracted and repelled each other; when the development of the fœtus was conceived as a repetition of the development of the race; in each case people regarded these phenomena as explained. For unfamiliar events familiar events were substituted, which the imagination readily followed.[1] The analogy at the basis of the explanation will vary from the crudest and wildest of resemblances, to such exact comparisons as the undulatory theory of light and electricity. But it is at bottom always comparison. The terminology of colors and numbers even was originally based on comparison. But when colors and numbers acquired significance independently of any definite objects and any definite connexion, they were raised to the abstract plane; and explanations which involve such elements are called *direct descriptions*, on the ground of the fact that the comparisons involved in them have been shorn of all concreteness and etherialised to the point of suggesting no obscuring connotations whatever. The notion of mathematical function itself has passed through this process; it was geometrical with Leibnitz; algebraical with John Bernoulli; and has become a general and almost purely logical concept with recent thinkers.

And so we may conceive the very instruments of mathematics itself as analogies and models, only of an ultimate and highly abstract order; *quantitatively, the course of nature runs as the course of certain functions, or mathematical models, runs;* and we thus bring under one conception the whole theory of scientific explanation. *Direct* description by absolute abstract analogy is the ideal;

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[1] See *The Open Court*, Vol. IX. p. 4450, "An Episode in the History of Philosophy," for the views of Adam Smith on this subject; and for a full exposition, cf. Mach's *Popular Scientific Lectures*, 3rd edition, Chicago, p. 236.

indirect, by more or less crude analogy, is most commonly the practice. (Terminology of Mach.) The former has been best exemplified in Galileo, Newton, Lagrange, and Kirchhoff; the latter in Faraday, Maxwell, and Lord Kelvin, who spoke in parables, dealt with so-called mechanical analogies and models and dynamical illustrations, and expressly disclaimed the reality of their fictions, but revealed withal a magnificent expanse of truth. Can this be said to be a reaction?

Professor Boltzmann, who distinctly mentions this development, seems to think so. But the reaction will, in our opinion, be found to be only apparent. The famous model from which Maxwell is said to have derived the equations that so touched the imagination of Hertz was itself the incorporation, or at least the suggestion, of those equations; and only in so far as it actually agreed in a formal aspect with reality was it of value to Maxwell. The *model* constituted the real discovery of Maxwell; if he had not hit upon the right model, he would not have hit upon the right equations; ultimately the crude model was abandoned and the equations alone substituted for reality.[1] A very rough diagram is a great help in solving a problem in geometry; but the roughness of the diagram is not the gist of the solution; the diagram merely helps to carry the thought and suggest the true relations; only in so far as the rough diagram contains the true relations is it essential to the result.

And so it was with the mechanical models and dynamical illustrations of Maxwell. "I have used them," says Maxwell, "to assist the imagination, not to account for the phenomena." And again, "The author of this method (referring to Lord Kelvin's 'Mechanical Representation of Electric, Magnetic, and Galvanic Forces') does not attempt to explain the origin of the observed forces by effects due to these strains in the elastic solid, but makes use of the mathematical analogies of the two problems *to assist the imagination* in the study of both."

We see, accordingly, that "description" in science involves (1) an elimination of the metaphysical elements from science, (2) economy and simplicity of the notions of science, and (3) the power of reconstructing nature. But we saw that there was more involved in it than a bare *recital* of experience. It involved *prediction* of experience and *reconstruction* of experience. It included that additional something which Goethe had in mind when he said, "Experience is only half of experience."

And what is Professor Boltzmann's attitude to this ideal? He believes it to be but a passing stage in the development of the theory of scientific explanation; he accepts it, but with qualifications.

Professor Boltzmann is a mechanicalist and an atomist in physical doctrine, a champion of pure analogy in scientific explanation and discovery, a repudiator of the absolute congruence of nature with the so-called laws of science, and so forth, and so forth. In all this he is upheld by the current conceptions of physics. For "description," he is prone to substitute, as we have seen, analogies, comparisons, and models, which are not necessarily bound to agree in all points with the phenomena which they are invented to explain, and which have the remarkable advantage over the "hypotheses" of the classical theoretical physicists, that no minor disaccord with nature destroys their reality! His ideals, as we have also intimated, lie rather with the school of Faraday, Maxwell, and Lord Kelvin, than with those of Galileo, Newton, Lagrange, and Kirchhoff. He is of the opinion that without the use of hypothetical elements no progress of knowledge is possible beyond the unsimplified noting of individual phenomena in memory. All simplification of memory-pictures, all apprehension of uniformities, and all rules designed to embrace complicated phenomena in a concise and simple manner, and to predetermine their course, rest upon the employment of representative pictures, or images, which have been obtained from the consideration of other simple phenomena and volitional acts, which are quite extrinsic to those to be explained. But it is only fair to say that his objections are not based upon the untenability of Kirchhoff's ideal, but rather upon the *unsuspected identity* of that ideal with the very doctrine of atomism which it would replace. For example, Professor Boltzmann holds that the naked enunciation of partial differential equations and the prediction of phenomena by the same, without reference to the physical or metaphysical forces or agents underlying these phenomena, constitute a process which itself involves an appeal to extrinsic elements. The equations are merely rules for constructing certain numeral series, or manifoldnesses, which have no direct and intrinsic connexion with the events themselves. So also the electro-magnetic equations of Maxwell contain hypothetical and adscititious elements,—elements which have been transferred from our observation of finite bodies and applied to purely theoretical fictions which have no more objective validity than have the atoms, and whose justification consists merely in the agreement of their results with experience, which is also the criterion of the validity of the atomic theory.

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[1] Boltzmann, *Katalog mathematischer und mathematisch-physikalischer Modelle*, *Apparate und Instrumente*, Munich, 1892: C. Wolf & Sohn.

Professor Boltzmann repudiates the contention that adscititious elements are added to the facts by atomism, and not by the partial differential equations; and, further, he would limit his atomism to the minimum amount of properties needful, entirely unadulterated with metaphysical additions. His atomism, thus, would itself constitute the nearest possible approximation to Kirchhoff's ideal. He admits the possibility of some other equally satisfactory explanation of nature, but before the atomistic doctrine is discarded he demands that one of equal clearness and exactitude be substituted for it. *Hic Rhodus, hic salta!* In fine, he claims the same abstract advantages and excellencies for his system as Kirchhoff does for his, and we are inclined to conclude that his partial opposition to the latter is due to a sincere endeavor to embrace under a single point of view the two ideals of research which have made most for the advancement of science. Virtually, the two are the same. The refinement of the notions of atoms, centers of force, etc., led ultimately to Kirchhoff's ideal, and it will ultimately dispense with that intricate scaffolding which entwines the edifice of recent physics. It is an ascending process of abstraction merely, in which the unessential is inevitably eliminated.

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Of the mechanics proper of the volume, we may say that Professor Boltzmann has sought to reinstate the science in its old form, as opposed to the newly-promulgated reconstructions, which have given it an entirely foreign dress. At the same time, his aim is to profit by the new criticisms and to avoid the old obscurities,—to free the old system of its defects while not destroying its familiarity. The work is complementary to his *Gastheorie*, which is not yet completed. The present volume is the first part; the second part will treat more particularly of the principles required in the *Gastheorie*. T. J. McCormack.

Des Méthodes dans les Sciences de Raisonnement. Par *J. M. C. Duhamel*, Membre de l'Institut, etc., etc. Five Vols. in 8vo. Paris: Gauthier-Villars, 55 Quai des Grands-Augustins. Price, for the entire work, 27 fr. 50 c. (Also sold singly.)

The present work is divided into five parts. It is not new, having first been published in the period from 1866 to 1872. It is a classical production in the philosophy of the exact sciences, but as it has not had the vogue in America or in England which from its general excellence and originality it deserves, and as its various parts have run through several editions, some of which are quite recent, we hold ourselves justified in giving a general characterisation of its objects and contents.

M. Duhamel was born in 1797, and died in 1872. He held relatively high rank as a mathematician, but his chief fame rests upon his successful activity as an educator, as an author of high class mathematical text-books, and as a shaper of methods of instruction. He was educated at the École Polytechnique, and was associated with the same institution as professor for more than thirty years. The idea of the present work on the philosophy of the exact sciences took its origin when he was a student engaged with the classical difficulties that, from the inception of philosophy, have ever disquieted the thinking mind. The career of instruction which he subsequently adopted involved, to his conscientious feeling, the obligation of removing these difficulties. It was not in his nature to affirm the exactitude of things concerning which he was himself in doubt; neither could he be content with possessing the conviction of that exactitude while unable to impart it to his pupils. His inward sense revolted against the counsel of D'Alembert, "Keep on, and faith will come to you." The imperative duty of his new calling, therefore, was, first, to remove the difficulties for himself, and, secondly, to give a clear and rigorous elucidation of them for the benefit of his pupils.

Such was the origin of the great work before us. It is the achievement of a mathematically trained mind, and exhibits the usual excellencies and shortcomings